

FEASIBILITY STUDY TO PRODUCE SOUND BARRIER
BRICK USING CRUMB RUBBER

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Feasibility Study to Produce Sound Barrier Brick Using Crumb Rubber

by

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CERTIFICATION OF APPROVAL

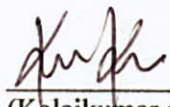
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A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
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BACHELOR OF ENGINEERING (Hons)
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Approved by,



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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



Siti Noreha Bt Che Bahrin

ABSTRACT

The wastes from automobile tires are increasing day by day. Some of them are reused in pavement material. Rubbers cannot be burned otherwise it will cause environmental issues. The dumping areas are insufficient as the wastes are increasing, led to mosquito breeding cases. In conjunction with that, a feasibility study was conducted to investigate potential of using crumb rubber in sound barrier wall application.

The literature review has proved that rubberized-brick is not only has high porosity, it is also act as a good sound insulator. The properties of rubber enhanced the noise reduction as the noise is absorbed by the material. The combination of two sizes of crumb rubber which are 3.35 mm and 0.60 mm managed to produce greatest slump compared to other sizes. Fourthly percentage volumetric replacement of sand found to be optimum mixture. Hence, by adopting 40 % replacement of sand with combination crumb rubber with 3.35 mm and 0.6 mm, it was revealed that the brick was not only lighter but also stronger; 5.36 MPa. A prototype barrier wall of 1 m width x 1 m length was build using crumb rubber-added bricks. Similar, traffic noise level was generated, using a single source. The noise reduction was recorded by determining the difference of noise level at front and behind the wall and varied the location. It was proved that the noise reduction of the new potential barrier wall is much better than the conventional barrier wall using normal brick.

From the study, the redundant tires can be reused to a newly product-based which is crumb rubber-added brick in sound barrier application. It is not only potential replace the conventional barrier wall but also solved two environmental problems, redundant waste tires and also traffic noise as well.

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CHAPTER 1

INTRODUCTION

Million tons of waste tires were produced in 2003; 87 % of them were generally reused as rubber pavement material, railway track pads, material for creating parks and recreation areas [1]. Rubbers, as can see in Figure 1.1; they cannot be dumped or burned; they are abandon waste product that need to be controlled. In order to overcome such problem, the tires must be consumed in various sectors. One of the potential applications of recycled rubber is in highway noise abatement. The properties of rubber itself enhance to noise reduction, thus it is the potential way to re-consume the abandon tires.



Figure 1.1: The abandon tires [1]

1.1 Background of Study

Nowadays, the major consumer of used rubber is the asphalt pavement industry [2]. The rubber has been processed to become crumb rubber and being used in various rubber material applications. Crumb rubber; a re-use rubber type that made from grinding rubber-products such as scrap tires, free from fiber and metal [2]. Fine rubber particle is ranged in size from 0.075 to 4.75 mm. In certain states, rubbers are burned to generate electricity; however the redundant tires produced seemed not adequate to reduce the waste tires. One of the applications of crumb rubber is in highway noise barrier [2].

First of all, the noise barrier is defines as solid obstructions built between highway and residential area [2]. It cannot block all the noise; however reduce the noise level by 5 to 10 decibels (dB). It can be effective depending on the material used. There are many types of barrier such as concrete barrier, wood barrier, timber barrier, earth berm barrier, and others (Figure 1.2). The common type is concrete barrier as it satisfied the noise reduction parameter. The new introducing of crumb rubber in brick to be applied for noise barrier is a great opportunity to highway technology. The material is a waste product that has been recycled to produce a new end product. Therefore, the new brick barrier can reduce the sound while encouraging to a greener world.



(a)



(b)

Figure 1.2: Some types of barrier wall

a) Wooden Barrier and b) Brick Barrier [2]

1.2 Problem Statement

Every year, million of automobiles tires were discarded around the world [1]. This lead to increasing of environmental solid waste as the accumulation of unused tires provoke to fire and health hazards. The critical question of how to reduce the unused tires becomes a major problem to people. That local waste product must be consumed and introduced to prevent from open burning of tires that lead to global warming. Beside that, dumping area became limited as the wastes produced increasingly by time. This problem contributed to arising of mosquito breeding cases; affected people's health. Previous invention of brick using fibre does not performed well as it cannot withstand to natural changes. It is vital to replace the conventional barrier wall by proposing the role of crumb rubber as it is a waste material that has high sound absorption.

1.3 Objectives

The purpose of this research is to produce sound barrier wall by using crumb rubber-added brick. The objectives of the study are:

- To re-consume redundant scrap tires to a newly product-based
- To study on the new potential barrier wall using crumb rubber
- To investigate replacement of the conventional barrier wall

1.4 Scope of Study

The limitation of the study concern on re-consuming locally product crumb rubber to produce highway noise barrier in Malaysia. The noise barrier that focused on this study is brick-type barrier. There are 4 types of brick; namely solid, cellular, perforated and frogged brick [3]. The solid brick is used instead of other types as it easy to manufacture under laboratory conditions. Furthermore, it required simpler mould compared to other

types of brick. It also does not contain holes, cavities or depression [3]. The topic is relevant to conduct as the barrier does not give any negative impact to environment. The locations selected to possess the sound data involved Jalan Sultan Azlan Syah in Ipoh and Ipoh-Utara Highway. These routes were identified to have residential area near to the massive traffic road, equipped by a respective barrier wall.

CHAPTER 2

LITERATURE REVIEW

There are lots of journal regarding crumb rubber as it was introduced into industrial-scale based in the 1950's [2]. However, not all of them discussing about the utilization of crumb rubber into noise barrier. Most of them proposed the application of crumb rubber on road pavement, meaning that just a few investigators studied on the properties of crumb rubber that correlate to noise abatement. After reviewing all the journals, the most suitable topics were selected to be reviewed. The sequence of the journal based on the historical review from different authors.

2.1 Crumb Rubber

In 1999, Zhu and Douglas studied on the manufacturing method of crumb rubber panel instead of the existing concrete panel [4]. Based on their understanding, the crumb rubber has a special thermo-mechanical and chemical-physical properties [4]. It is light in weight, durable and can withstand with environmental changes. Furthermore, it is a non-toxic and inert material. Zhu and Douglas mentioned that the rubber panel has high air porosity compared to concrete panel [4]. Therefore, it leads to high sound absorption that is significant to effective noise barrier. The most parameter that was concerned by them is Acoustical Absorption Coefficient (AAC) which represents the capability of a material to absorb noise. Besides, a sound energy defines as a sound wave that carried certain amount of energy.

The best sound reduction has less value of sound energy reflected. It also produced a value $AAC=1$ in which all the sound energy is absorbed by that material. In proving the statement, Zhu and Douglas conducted an experiment to compare the AAC value of three different materials which are crumb rubber, concrete and Carsonite barrier. Carsonite barrier consists of hollow panels with planks of reinforced composite material,

filled with crumbed rubber [4]. Figure 2.1 shows the result of the experiment and it is proved that crumb rubber based product has greater acoustical absorption compared to other materials [4].

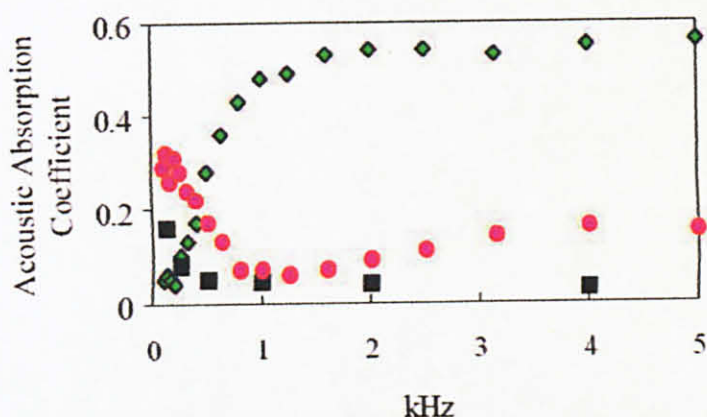


Figure 2.1: Acoustic absorption coefficient versus frequency [4]
 Legend: ■ Concrete barrier ● Carsonite barrier ◆ Crumb rubber mix

In 2008, the recent study on thermal and sound properties of crumb rubber concrete panel was conducted by Piti [5]. The scope of the study is to re-use scrap tires produced locally in Thailand [5]. The study developed by Piti is quite similar to research done by Paki and Bulent which is replacement of crumb rubber to sand with ratio from 10 to 30 % for respective sample. According to Piti, crumb rubber is not suitable for structural application as it has poor strength; however it performed well as insulator [5]. The author prepared eight samples of block to be experienced for three tests which are density and void (ASTM 642-97), steady-state flux measurement, and acoustic determination of sound absorption coefficient [5].

The mix proportion for the sample mentioned at 1.00:0.47:1.64:1.55 which is cement: water: fine aggregate: coarse aggregate. As stated in Table 2.1, crumb rubber no. 6 (passing ASTM sieve No. 6), no.26 (passing ASTM sieve No. 26) and combined no. 6+26 were used to replace fine aggregate by weight. In his study, Piti tested sound absorption under two different frequencies which are 1) Low-mid (125, 250, 500 Hz) and 2) High-frequency (1000, 2000, 4000 Hz) [5]. The result shows in the Table 2.2 in which it is concluded that crumb rubber concrete is better sound absorber at high-

frequency than plain concrete which suitable for highway application. The noise reduction coefficient is displayed in the Figure 2.2. It is indicated that crumb rubber is 36 % greater sound resistance properties than plain concrete [5].

Table 2.1: Detail and assigned designation [5]

Designation	w/c Ratio	Weight per m ³		Cement (kg)	Coarse agg. (kg)	Fine agg. (kg)	Water (kg)
		Crumb rubber					
		No. 6	No. 26				
PC	0.47	0.0	0.00	478.7	741.5	783.8	225.0
6CR10	0.47	78.4	0.00	478.7	741.5	705.5	225.0
6CR20	0.47	156.8	0.00	478.7	741.5	627.1	225.0
6CR30	0.47	235.2	0.00	478.7	741.5	548.7	225.0
626CR10	0.47	39.2	39.2	478.7	741.5	705.5	225.0
626CR20	0.47	78.4	78.4	478.7	741.5	627.1	225.0
626CR30	0.47	117.6	117.6	478.7	741.5	548.7	225.0
26CR10	0.47	0.00	78.4	478.7	741.5	705.5	225.0
26CR20	0.47	0.00	156.8	478.7	741.5	627.1	225.0
26CR30	0.47	0.00	235.2	478.7	741.5	548.7	225.0

Table 2.2: Average sound absorption coefficient [5]

Concrete type	Frequency (Hz)																																			
	125						250						500						1000						2000						4000					
	a			SD			Uncertainty			a			SD			Uncertainty			a			SD			Uncertainty			a			SD			Uncertainty		
	(%)									(%)									(%)									(%)								
PC	23.0	1.4	1.7				11.5	0.7	2.1				6.8	1.1	2.1				24.5	0.7	3.2				9.1	0.1	2.0				20.1	0.1	1.8			
6CR10	23.0	2.8	1.8				12.0	1.4	2.1				12.1	0.1	2.1				31.5	4.9	2.7				17.0	1.4	2.3				25.0	1.4	2.4			
6CR20	23.5	0.7	1.8				11.3	0.4	2.2				9.5	0.7	2.0				37.0	2.8	3.0				15.1	0.1	1.8				24.0	1.4	1.8			
26CR10	24.5	0.7	1.9				11.0	0.7	2.1				10.0	1.4	2.1				26.5	0.7	3.1				16.0	1.4	1.7				27.5	0.7	2.0			
26CR20	24.5	0.7	1.8				11.3	0.4	2.3				9.3	1.8	2.1				29.0	1.4	2.2				23.5	2.1	2.1				27.1	0.1	1.9			
626CR10	25.1	0.1	1.8				11.5	0.7	2.0				9.5	0.7	2.0				29.0	1.4	2.9				15.1	0.1	1.9				24.8	1.1	1.9			
626CR20	25.5	0.7	1.8				12.2	0.2	2.1				13.5	0.7	2.5				30.1	0.1	3.0				20.3	0.4	1.8				30.0	5.7	2.1			

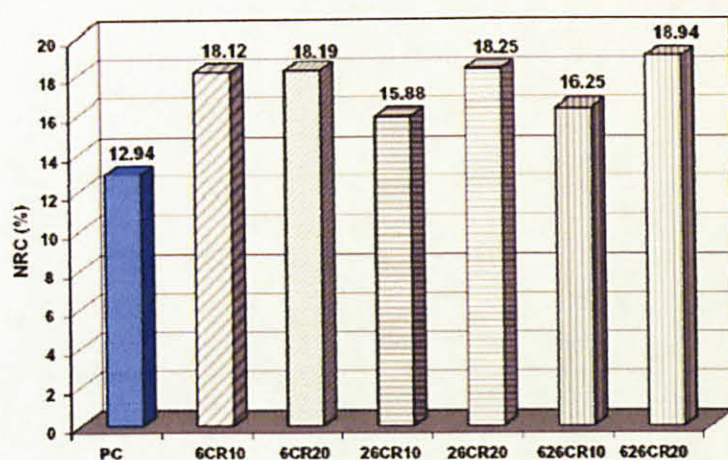


Figure 2.2: Noise reduction coefficient [5]

2.2 Crumb Rubber into Brick

In 2007, Paki and Bulent conducted a research on the feasibility of using crumb rubber as aggregates in cementitious composit to create ready-used brick with improved thermal insulation properties [6]. They found that the new brick can be used for low cost building that differs in composition from the existing brick. The size of crumb rubber used is in range of 0.075 to 4.75 mm while the sand is taken from Goksu River, Turkey [6]. Table 2.3 shows the mixture proportion of the brick samples complied with BS 6073. There are seven different rubberized samples with varying percentage of crumb rubber from 10 to 70 %. R-10 sample means 10 % of sand volume is replaced by crumb rubber. After mixing process, each cube experienced slump test and the result. From the same table, it is proved that R-40 obtained greatest slump value which is 6.5. The slump test represents the workability of the concrete.

Table 2.3: Fresh mixture properties for one brick sample [6]

Fresh mixture properties for one brick sample

	Cement (g)	Water (g)	Sand (g)	Crumb rubber (g)	Total (g)	Slump (cm)
Control mix	952	429	2619	-	4000	1.5
R 10	952	429	2357	101	3838	-
R 20	952	429	2095	202	3678	4.0
R 30	952	429	1833	302	3517	-
R 40	952	429	1572	403	3356	6.5
R 50	952	429	1310	503	3194	-
R 60	952	429	1048	604	3033	2.5
R 70	952	429	786	705	2872	-

The appearances of eight brick samples including control mix were shown in Figure 2.3. The investigators found that the more crumb rubber added, the better the brick appearance [6]. There are other tests conducted by them on water absorption, compressive strength, and flexural strength which conformed to ASTM C 67-03a [6]. They concluded that the replacement of crumb rubber as aggregate in mix proportion reduces about 29 % unit weight of the brick [6]. High percentage replacement of crumb rubber with conventional sand does not exhibit sudden brittle fracture means that the energy absorption capacity is high.



Figure 2.3: Appearance of brick sample [6]

2.3 Curing Effect

A study has been conducted in 1998 regarding the effect of curing conditions on compressive strength of brick aggregate concrete by Sohrabuddin and Saiful Amin [7]. The authors used crushed brick as coarse aggregate in two concrete mixes that were designed for a particular strength as shown in Table 2.4.

Table 2.4: Properties of the aggregates [7]

Ingredients	Quantity lb./yd ³	
	Batch 1	Batch 2
Cement	525.00	525.00
Fine Aggregate	1356.28	1251.95
Coarse Aggregate	1275.47	1483.30
Water	299.00	299.00

Different series of interrupted curing were applied on the concrete specimens and the compressive strength for both mixes was tested. It is stated that sufficient supply of moisture is needed to make sure the hydration for reducing porosity to the desired strength and durability can be achieved. A 3-day curing gives 75 to 80% of the 28-day strength while 7-day will allow concrete to reach 28-day moist cured strength. Curing at any stage is essential in order to overcome the losses due to discontinuity in curing [7]. The authors also found that crushed brick aggregate was more sensitive to the

interrupted curing process compared to the stone aggregate concrete. It is significant to conclude that the strength of the specimen increased when the curing process beyond 28-day as shown in the Figure 2.4.

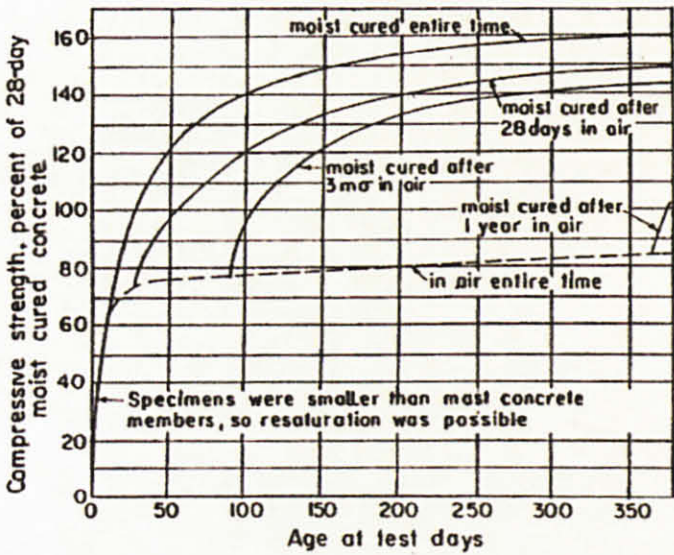


Figure 2.4: Effect of curing conditions on compressive strength of stone aggregates concrete [7]

CHAPTER 3

METHODOLOGY

This chapter brief on the methodology on how research being conducted within time frame in order to achieve the objective of the project. It also explained the procedure in making the brick and the experimental setup of the barrier wall to measure the noise reduction. The project methodology is displayed in Figure 3.1.

3.1 Project Methodology

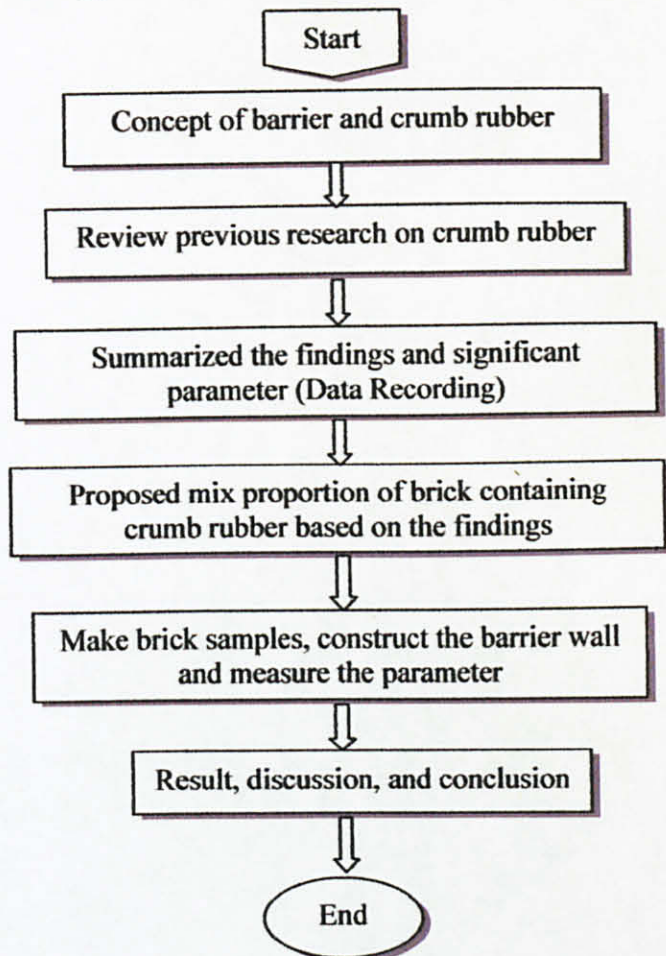


Figure 3.1: Methodology Flow Chart

3.2 Basic Function of Barrier

A noise barrier can reduce 5 dB noise level when its height is exceeded the line of sight of the receiver. As it exceeded the line, the reduction of noise is about 1.5 dB for each meter of barrier height as shown in Figure 3.2.

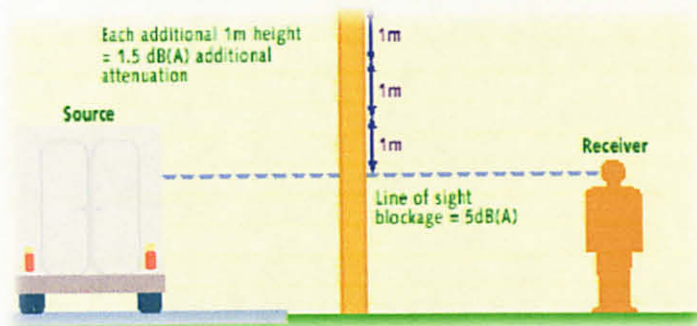


Figure 3.2: Concept of noise barrier [2]

3.3 Size of Crumb Rubber

Based on the journals reviewed, the author chose two different sizes of crumb rubber which are; 3.35 mm and 0.60 mm as shown in Figure 3.3. The reason of selecting that particular size is due to the greater noise reduction compared to other size. The amount of crumb rubber that used for a brick is about 403g which represented 40 % replacement of sand used to make a brick sample. The percentage was chosen as it was proved that 40 % replacement of sand to crumb rubber will give greatest slump value compared to other percentage.

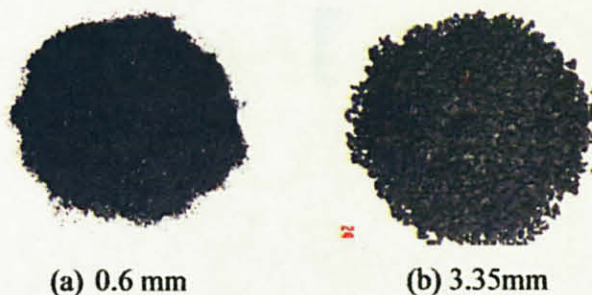


Figure 3.3: Crumb rubber

3.4 Sound Barrier Wall Using Crumb Rubber-Added Brick

3.4.1 Preparation of Formwork

Figure 3.4 shows the formwork that was made from plywood and has a dimension of 105 x 75 x 225 mm per sample. For the cube testing purpose, two steel moulds with dimension 100 x 100 x 100 mm were used. Basically, the formwork and the steel moulds were greased first before placing the fresh mixes to ease the dismantling process later.



Figure 3.4: Formwork for 12 samples

3.4.2 Sieve Analysis

Prior to brick manufacturing, the materials such crumb rubber and sand were graded using sieve shaker before the mixing process started as shown in Figure 3.5. It was carried out to maintain the correct grading of sand that is to be used. The sieve meshes of several sizes such as 1.18 mm, 600 μm , 425 μm , 300 μm and 150 μm were used for the sand. Besides, the crumb rubber was sieved in order to obtain the required sizes which are 3.35 mm and 0.60 mm.



Figure 3.5: Sieving

3.4.3 Mixing Process

The mix design used for the whole project was adopted from the previous research conducted by Paki and Bulent as stated in Table 3.1. The type of cement used is Ordinary Portland Cement (OPC). During mixing process, crumb rubber, sand and cement were mixed in a concrete mixer for 1 minute without any water. Water was poured while mixer is rotating to enhance crumb rubber scattered uniformly with additional three minutes mixing process. Figure 3.6 summarized the procedure of making the brick.

Table 3.1: Mix properties of one brick sample

Cement (g)	Water (g)	Sand (g)	Crumb rubber (g)	Total (g)
952	554	1572	403	3481

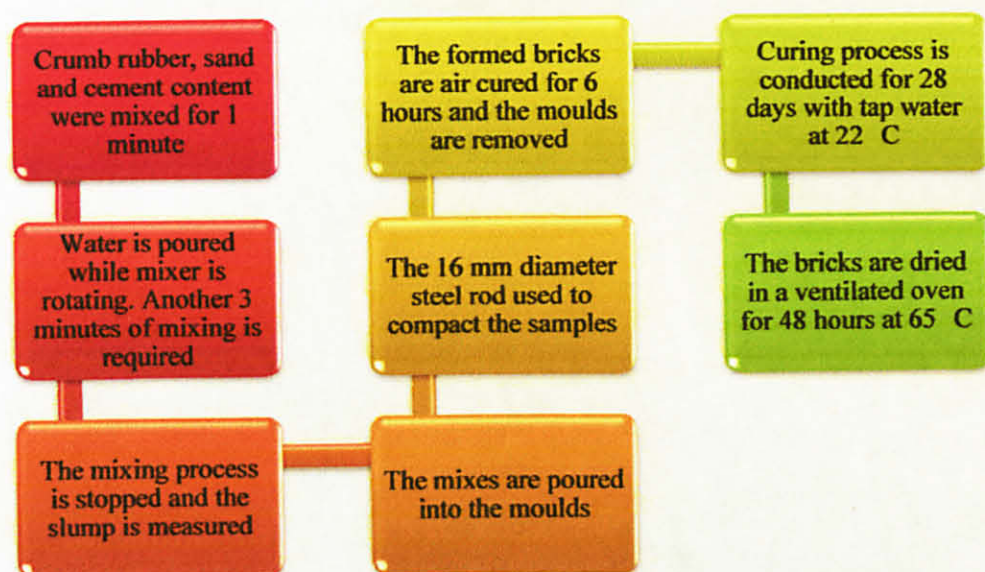


Figure 3.6: Procedure of brick making [6]

3.4.4 Slump Test

Upon to the mixing process, the slump test was conducted to measure the workability of the fresh mixes. The slump cone was filled with the mixes by three layers in which it was tamped with 25 strokes by using a tamping rod. The slump cone was removed vertically and the slump was measured by determining the difference between the height of the slump cone and the highest point of the mix that being tested as shown in Figure 3.7. The result was recorded in millimeter unit and will be discussed further in the next chapter.



Figure 3.7: Slump test

3.4.5 Casting

The fresh mix was poured into the formwork that has been prepared earlier and compacted by using steel rod to remove the air trap. Figure 3.8 displayed the casting of 12 samples. The formwork was dismantled after 24 hours air-cured process.



Figure 3.8: Casting

3.4.6 Curing

The physical properties of concrete mostly depend on the extent of hydration of cement during curing process. It is the mechanism in which the cement will harden and impart the strength of the concrete simultaneously. Curing process took place for 28 days in a cure tank, filled with 22 °C of tap water as shown in Figure 3.9.



Figure 3.9: Curing tank

3.4.7 Compressive strength

After the curing process took place, the samples were tested for compressive strength to measure the strength. The samples were dried first before the test started as the compression test machine is sensitive to the present of water. The compressive strength was determined by dividing the maximum load with the applied load area which is 100 mm x 100 mm of the cube samples as can be seen in Figure 3.10.



Figure 3.10: Cube compressive strength

3.4.8 Oven-dried process

The final step in making the brick was the oven-dried process whereby the brick samples were dried for 48 hours in a ventilated oven at 65°C temperature as shown in Figure 3.11. After 48 hours period, the bricks were removed from the oven and ready to be used for the barrier wall.



Figure 3.11: Oven-dried process

3.4.9 Constructing wall and experimental testing

The experimental set-up of the barrier wall is displayed in Figure 3.12. The wall is built in 1 m width x 1 m height with each brick dimension is 105 x 75 x 225 mm. The additional barrier is constructed for both sides to allow the reflection of sound. It is also to avoid the sound from diverging to other angle which may contribute to error. The source of noise is generated behind the wall while the receiver (sound meter) placed at front of the wall. The source of noise and the receiver should be at the same level. The reduction of noise level is measured by comparing the noise level at both sides in order to test the efficiency of the barrier wall using crumb rubber-added brick.

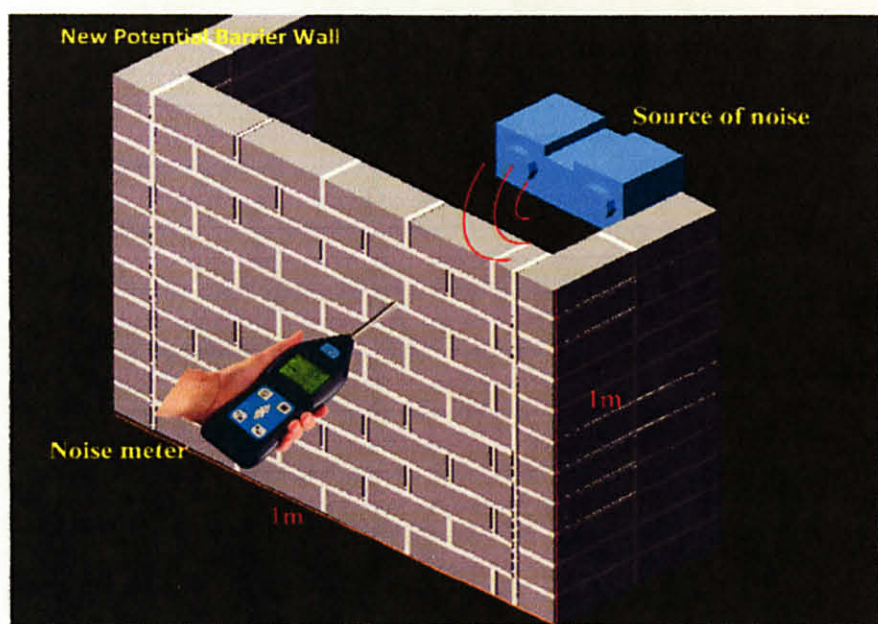


Figure 3.12: Experimental set-up

CHAPTER 4

RESULT AND DISCUSSION

This chapter will discuss on the result that has been obtained throughout the project on the efficiency of the new potential barrier wall using crumb rubber-added brick.

4.1 Sound Level

Sound intensity is recognized as loudness; computed on a relational scale in decibel unit [8]. It entailed a standard sound level against which they are evaluated. Standard Sound Pressure Level (SPL) is $0.0002 \text{ dynes/cm}^2$. Double intensity of sound can be observed for the increasing of sound pressure by 6 dB [8]. Table 4.1 displayed the sound pressure levels of common sounds.

Table 4.1: Sound pressure level of common sounds [8]

Sound	dB
Rocket launching pad	180
Jet plane	140
Gunshot blast	130
Car horn	120
Pneumatic drill	110
Power tools	100
Subway	90
Noisy restaurant	80
Busy traffic	75
Conversational speech	66
Average home	55
Library	40
Soft whisper	30

Generally, noise levels with smaller than 80 dBA are believed as safe while 85 dBA is the superior limit for continuous exposure during eight hours without protection [9].

4.2 Data Measurement

The author recorded sound level at two different locations; Jalan Sultan Azlan Shah (Refer Appendix B) and Ipoh-Utara Highway (Near to Kawasan Gunung Helang) (Figure 4.1, 4.2 and 4.3). The equipment being used was Sound Level Meter (ONO SOKKI Model LA-1240) as shown in Figure 4.4.



Figure 4.1: Jalan Sultan Azlan Shah



Figure 4.2: Ipoh-Utara Highway (Front Wall)



Figure 4.3: Ipoh-Utara Highway (Behind Wall)



Figure 4.4: Sound Level Meter (ONO SOKKI Model LA-1240)

The measurement was taken during peak hour; around 1 to 3 p.m. The result is shown in the Table 4.2.

Table 4.2: Sound level (front wall) at Jalan Sultan Azlan Shah and Ipoh-Utara Highway

Item	Sampling Location	
	1 (Jalan Sultan Azlan Shah)	2 (Ipoh-Utara Highway)
Source of noise	Vehicles	Vehicles
Noise level (dBA) after:		
1 minute	75.1	84.5
2 minutes	86.5	89.3
3 minutes	89.7	85.1
4 minutes	89.1	82.7
5 minutes	75.8	86.4
6 minutes	78.7	87.3
7 minutes	83.6	86.7
8 minutes	79.6	82.9
9 minutes	72.7	83.6
10 minutes	80.4	88.3
Average noise level (dBA)	81.1	85.7

Based on the recorded data, the average noise level for Location #1 is **81.1 dBA** and **85.7 dBA** for Location #2. The value for Location #2 is greater than #1 due to different type of road in which the speed limit for highway usually 110 km/h; resulted to greater noise level generated by vehicles.

There were existing barriers at both locations whereby the heights of barrier are approximately 2 meter and 4 meter respectively. The sound level was recorded at front wall as shown in Figure 4.2. Beside that, the author also recorded sound level behind the wall at Location #2 as shown in Figure 4.3. The Location #1 is the private area whereby accessibility was prohibited or was not permitted to enter. This constraint leads to unavailable data of behind wall at Location #1. The result is shown in Table 4.3.

Table 4.3: Sound level (behind wall) at Ipoh-Utara Highway

Item	Sampling Location
	Behind Wall (Ipoh-Utara Highway)
Source of noise	Vehicles
Noise level (dBA) after:	
1 minute	75.4
2 minutes	74.6
3 minutes	77.9
4 minutes	79.7
5 minutes	76.1
6 minutes	77.3
7 minutes	73.2
8 minutes	75.1
9 minutes	74.9
10 minutes	77.8
Average noise level (dBA)	76.2

It is stated that a noise barrier can reduce 5 dB noise level when its height is exceeded the line of sight of the receiver [2] as described in the previous chapter. As it exceeded the line, the reduction of noise is about 1.5 dB for each meter of barrier height [2].

Calculation:

The calculation was computed to determine the total noise reduction for Location #2. The detail as showed below:

A) Theoretical Value

- ✓ Height of receiver: 1.4 m
- ✓ Height of wall: 4 m (approximately)
- ✓ Additional height: $(4-1.4) \text{ m} = 2.6 \text{ m}$
- ✓ Noise reduction= $1.5 (2.6) \text{ m} = 3.9 \text{ dBA}$
- ✓ Total noise reduction: $5 \text{ dBA} + 3.9 \text{ dBA} = \underline{\underline{8.9 \text{ dBA}}}$

B) Actual Value

- ✓ Average noise level (front wall): 85.7 dBA
- ✓ Average noise level (behind wall): 76.2 dBA
- ✓ Noise reduction= $(85.7-76.2) \text{ dBA} = \underline{\underline{9.5 \text{ dBA}}}$

C) Percentage Error

$$\begin{aligned} &= \left[\frac{\text{Theory} - \text{Actual}}{\text{Actual}} \right] \times 100 \\ &= \left[\frac{8.9 - 9.5}{9.5} \right] \times 100 \\ &= \underline{\underline{6.3 \%}} \end{aligned}$$

The differential might be caused due to human error; did by the author during recording the data as the sound meter recorded the sound manually. Other possible cause might be the level of accuracy of the equipment; range of linearity of the sound meter is around 85 dBA [10].

4.3 Quantities of Brick and Cement Required

The quantities of brick and cement that used for the whole project were stated as the following:

- It was about 94 nos. of bricks needed for constructing the barrier wall in which 50 bricks were used for the main wall while the rest 44 bricks were installed at the both side of the wall.
- The cement needed for 12 bricks is almost 12 kg. Therefore, 2 bags of cement were used to produce such number of bricks.

4.4 Sieve Analysis

The result of sand analysis is shown in Figure 4.5. The sand was well graded with the largest size is 1.18 mm. Most of them are retained at sieve size of 0.6 mm. The sand that used in the project was not too dry to avoid from less bonding with cement during mixing process.

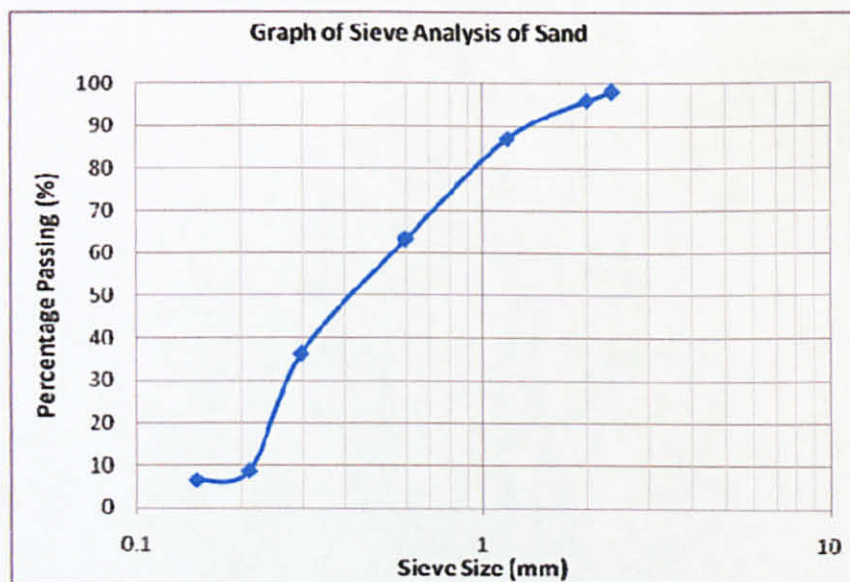


Figure 4.5: Sieve Analysis

4.5 Brick Testing

4.5.1 Slump Test

The result of slump test for each mix is shown in Table 4.4. Higher slump indicates the greater workability of the mix itself.

Table 4.4: Slump value

Mix No.	Slump (cm)
1	6.8
2	7.2
3	7.4
4	8.2
5	6.5
6	6.9
7	7.0
8	6.6
Average	7.1

Figure 4.6 displayed the slump test that has been conducted. The measured average slump is 7.1 cm. It proved that the combination of crumb rubber sieve no.6 and 26 can produce greater slump and exceed the slump value conducted by Paki and Bulent, which is 6.5 cm [6].



Figure 4.6: Slump measurement

4.5.2 Compressive Strength

The author used 100 x 100 x 100 mm cube to test the strength as shown in Figure 4.7. The brick exhibited similar strength either it is tested by using cube or brick. The result of the compressive strength is shown in Table 4.5. The minimum compressive strength for non-load-bearing concrete masonry unit is 3.5 MPa as stated in ASTM C129 [11]. The strength of the new crumb rubber-added brick is 5.36 MPa whereby it exceeded the required strength stated in the standard.

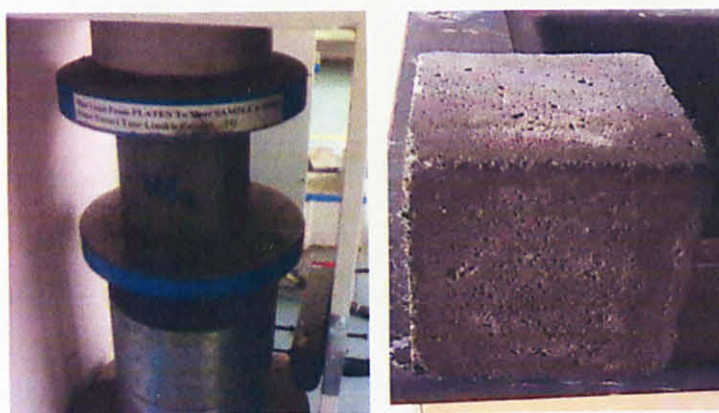


Figure 4.7: Cube testing

Table 4.5: Compressive strength for cubes tested

Cube No.	Unit Weight (g/cm ³)	Pace Rate	28-day strength (MPa)
10-2	1.68	3.0	-
22-2	1.75	3.0	5.42
21-2	1.68	3.0	5.12
26-2	1.76	3.0	5.62
5-3	1.77	3.0	5.23
9-3	1.73	3.0	5.41
Average	1.73		5.36

4.5.3 Curing Process

After dismantling the formwork, the bricks were cleaned and ready to be cured. The tap water has been used as the pH of the tap water is 7.5; natural pH standard. The curing process was selected to be 28 days as the strength of the bricks are higher compared to 7 or 14 days [7]. The curing process can be viewed in Figure 4.8.



Figure 4.8: Curing process

4.5.4 Oven-dried Brick

Once the bricks finished the curing process, the bricks were dried into oven for 48 hours with temperature 65°C . The appearances of the dried-brick after removing from oven were shown in Figure 4.9.



Figure 4.9: Dried-brick appearance

4.6 Noise Reduction Experiment

Upon the completion of brick making, a sound barrier wall was constructed in the laboratory by using the crumb rubber-added bricks as shown in Figure 4.10. The wall was barricaded by plywood to avoid the noise to be diverted and decay.

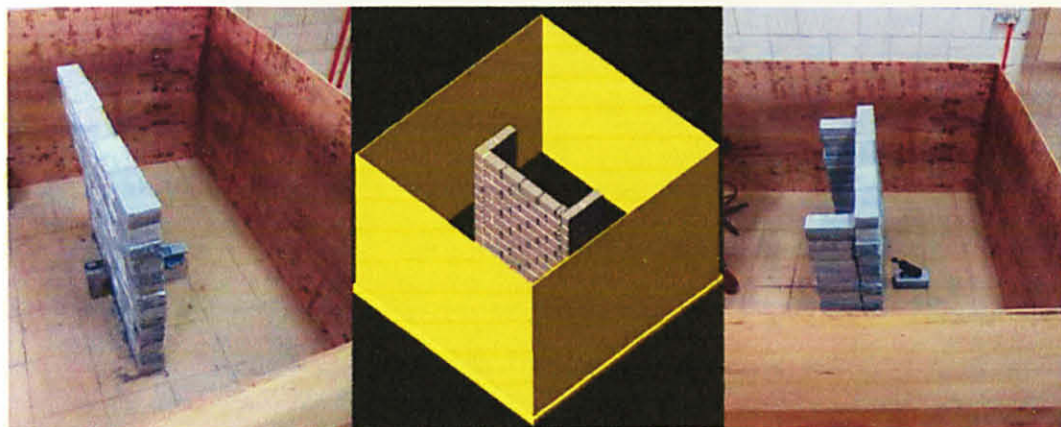


Figure 4.10: Sound barrier wall

There were several attempts that had been conducted in order to measure the efficiency of the new barrier wall at different locations as stated in Figure 4.11.

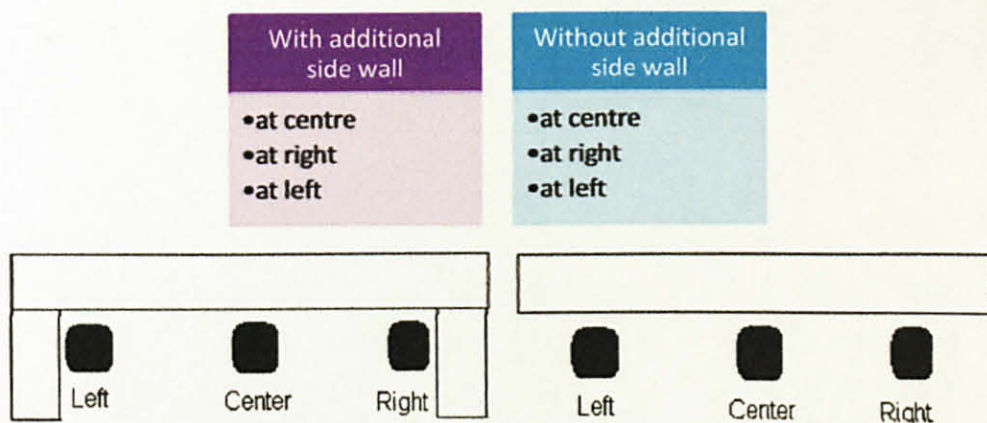


Figure 4.11: Method of noise measurement

4.6.1 Source of noise

Initially, the source of noise was recorded to create similar noise level that taken during field measurement. The result of source of noise can be seen in Figure 4.12.

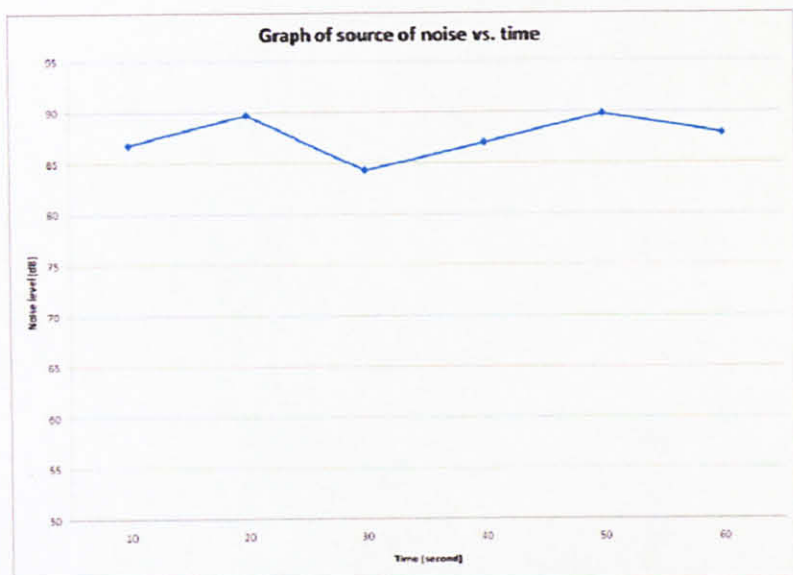


Figure 4.12: Graph of source of noise vs. time

Based on the above graph, the loudest sound created almost 90 dBA while the average of noise in 60 seconds is about 88 dBA. The author used the same source of noise which is recorded sound for each kind of trial.

4.6.2 Barrier wall without additional side wall

The first attempt was to measure the noise reduction of barrier wall without additional side wall. The source of noise and the noise meter (receiver) were aligned at the same level. The location of the source of noise and also the noise meter (receiver) were manipulated at 3 different locations namely; centre, right, and left of wall. The results for the three experiments were shown in Figure 4.13 until 4.15.

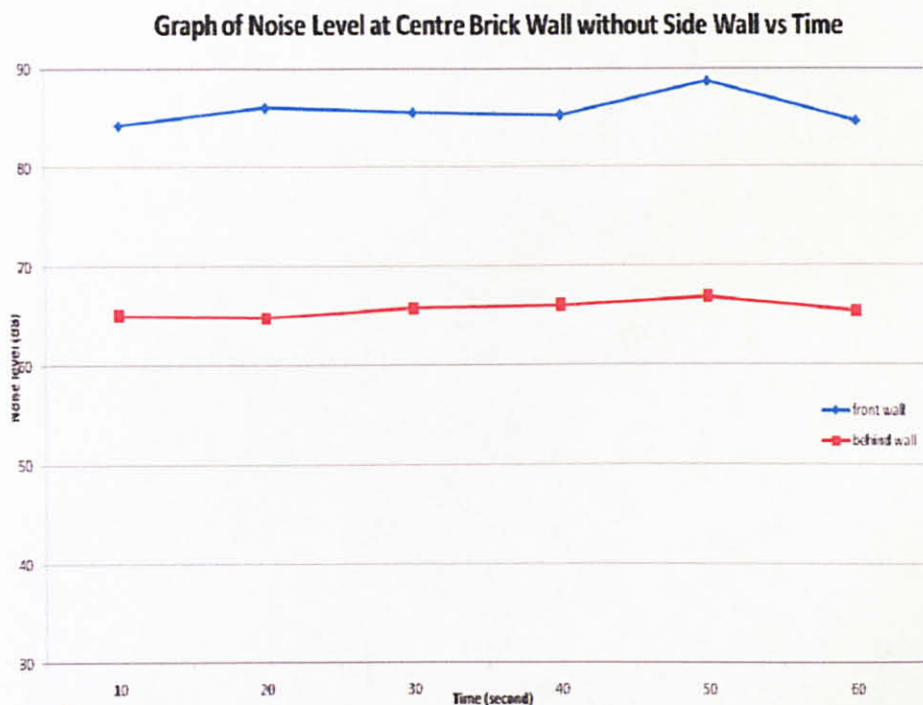


Figure 4.13: Graph of noise level at centre brick wall without side wall vs. time

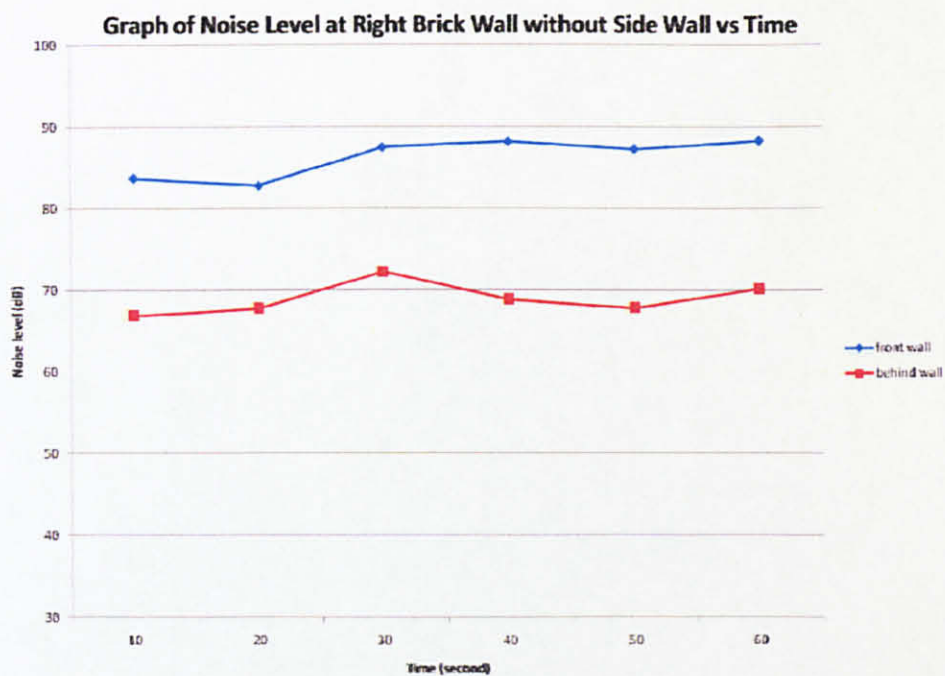


Figure 4.14: Graph of noise level at right brick wall without side wall vs. time

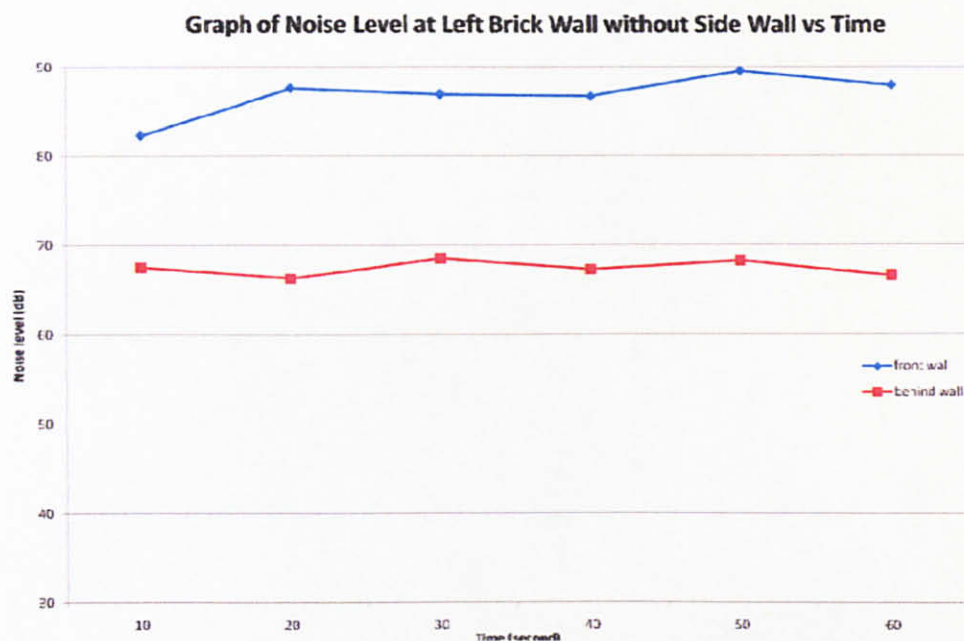


Figure 4.15: Graph of noise level at right brick wall without side wall vs. time

It can be said that the noise level at front wall for three different locations is below 90 dBA. The noise is not directly reflected back to the wall as it spread to other angle. The average of noise reduction for barrier wall without additional side wall is about **18.87 dBA**.

4.6.3 Barrier wall with additional side wall

The noise reduction for barrier wall with additional side wall was tested with similar method to the previous attempt, except with the side wall at both sides. The results were displayed in Figure 4.16 to 4.18.

Graph of Noise Level at Centre Brick Wall with Side Wall vs Time

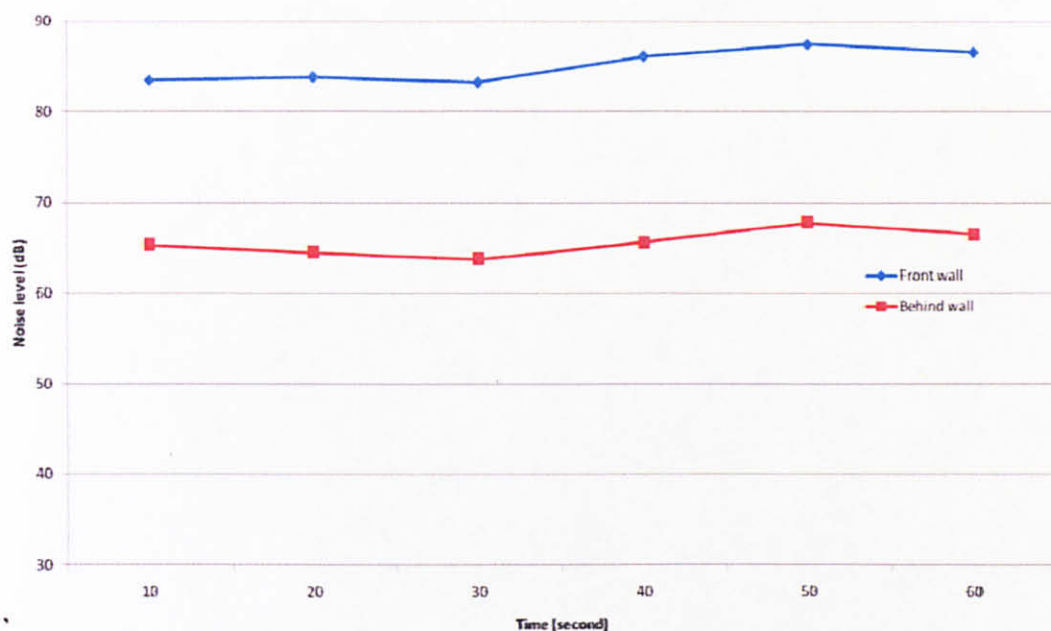


Figure 4.16: Graph of noise level at centre brick wall with side wall vs. time

Graph of Noise Level at Right Brick Wall with Side Wall vs Time

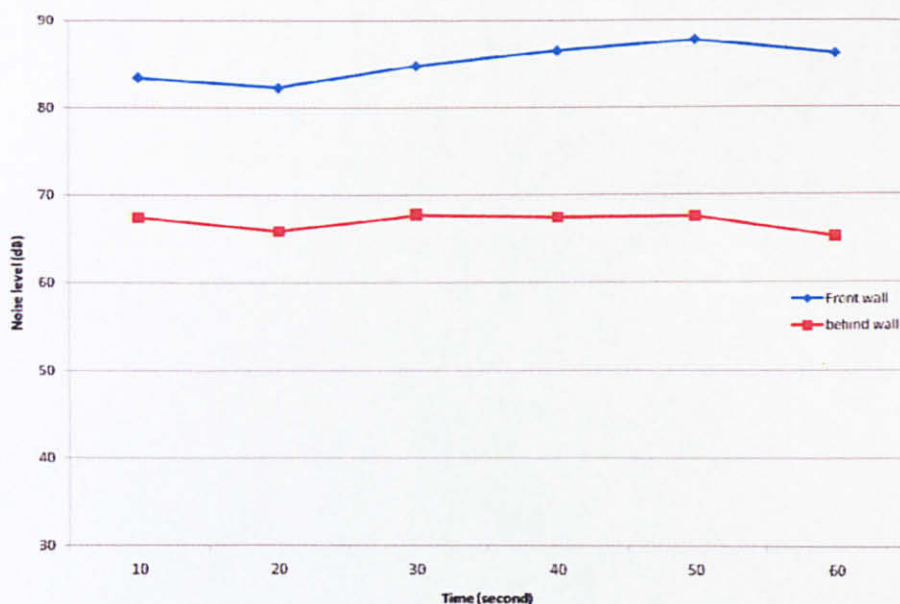


Figure 4.17: Graph of noise level at right brick wall with side wall vs. time

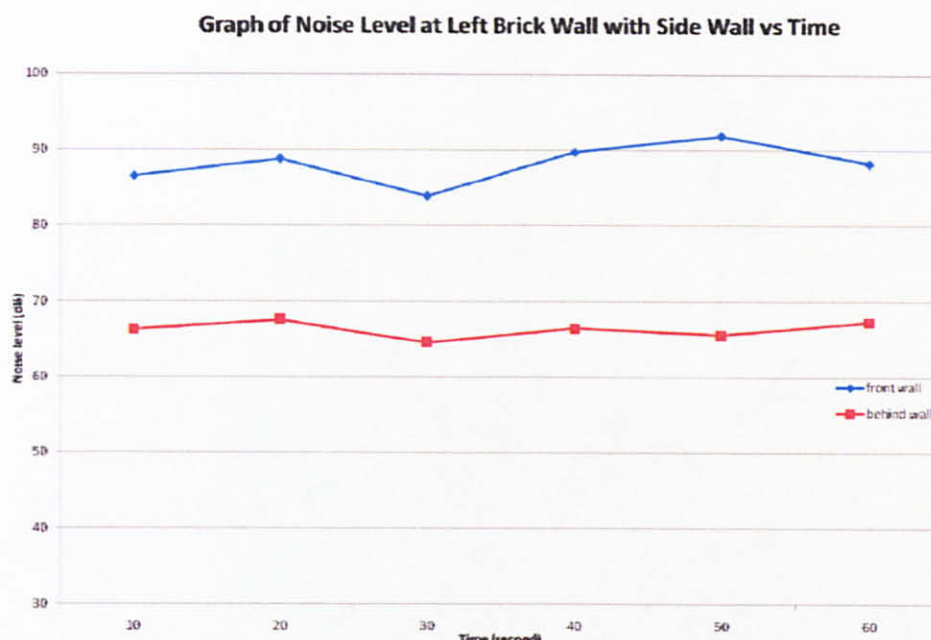


Figure 4.18: Graph of noise level at left brick wall with side wall vs. time

Based on the three graphs, the noise reduction is more consistent compared to the barrier wall without side wall. It can be justified that the noise reduction at the centre of wall is lower compared to other locations which are right and left as the noise is reflected back by the side wall. It is not only will create louder noise, but also high noise reduction. However, the difference between the three locations is not big as the wall is constructed in small scale of dimension. The average noise reduction for three locations is **19.87 dBA** which greater than barrier wall without side wall. The real barrier wall may have or not the additional side wall since the purpose of introducing the side wall in this study is to prohibit influence of generated noise. The field measurement at Ipoh-Utara Highway barrier wall achieved 9.5 dBA while the new potential barrier wall using crumb rubber-added brick managed to get greater noise reduction. Therefore, crumb rubber is a good material compared to the concrete in terms of sound absorption.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Noise barrier is installed at the highway that has residential area. It cannot block all the noise. The function of noise barrier is to reduce the noise level by 5 to 10 dB depending on the material used. The conventional concrete barrier is not good in sound absorption as the sound is reflected back to the surrounding. Rubber; it is a good insulator and enhances the sound absorption at high noise frequency such as highway. Based on the advantages of crumb rubber in noise abatement, a new idea to introduce the application of crumb rubber in sound barrier wall was conducted in this project. The noise reduction obtained was significant compared to conventional barrier wall. The new potential barrier wall using crumb rubber-added brick is the solution of the problems regarding the abundant tires and also the limited dumping area. Hence, it is concluded that:

- ✓ The redundant scrap tires can be re-consumed to a newly product based such as crumb rubber-added brick which is not only lighter but also durable in terms of strength
- ✓ The sound barrier wall using crumb rubber-added brick is potential to be used at highway in Malaysia as it is proved that crumb rubber is a good sound absorber compared to conventional concrete
- ✓ The conventional barrier wall can be replaced by the new barrier wall using crumb rubber-added brick wall as it encourages greener world and effective in noise reduction

5.2 Recommendation

Crumb rubber is not good in fire fighting, low creep performance and relatively poor modulus [12]; therefore the author recommends on the further research that suitable additive can be added into the brick to prevent fire problem. The appearance of the brick might be vital in the future for acoustical reason; hence the author proposed advance study to improve the appearance of the brick. The other recommendation is to introduce a new shape of brick such as interlocking concrete masonry unit (CMU) that implemented in Industrialized Building System (IBS) so that it is easy to be installed. In addition of that, a full scale of study can be conducted in future to investigate other properties of the rubber-added brick that is not covered under this study.

CHAPTER 6

ECONOMIC BENEFITS

In this study, it was about 94 bricks were required to manufacture 1m width x 1m length sound barrier wall. There are four raw materials needed to make the brick namely; sand, cement, crumb rubber and water. The costs for each material are shown in Table 6.1.

Table 6.1: Cost for raw material

Raw material	Price (RM/kg)
Sand	0.018 ^[1]
Cement	0.320
Crumb rubber	0.700
Raw material	Price (RM/m ³)
Water	3.00 ^[2]

^[1] The price was obtained from local sand supplier for washed-sand type

^[2] Based on Lembaga Air Perak (LAP)

The raw materials required to make one brick are shown in Table 6.2.

Table 6.2: Mix proportion for one brick

Sand (kg)	Cement (kg)	Crumb Rubber (kg)	Water (m ³)
1.572	0.952	0.403	0.000554

Therefore, the cost for each brick was calculated as stated in Table 6.3.

Table 6.3: Cost for one brick

Raw material	Price (RM)
Sand	0.030
Cement	0.300
Crumb rubber	0.280
Water	0.002
TOTAL	0.612

The cost for each brick is RM0.612 hence for 94 bricks involved RM57.53. The market price for normal brick without crumb rubber is about RM0.50 and vary based on the availability of raw material. However, the price for the rubber-added brick can be lower for the mass production. The prices for the sand and cement are cheaper for industrial usage while for the crumb rubber; the price can be lower for every metric tonne of quantity ordered.

Thus, the project is not only can minimize the cost for barrier wall but also can recycle abandon tires to produce a beneficial product-based such sound barrier wall using crumb rubber.

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APPENDICES

A: Map of Jalan Sultan Azlan Shah (Location #1)



B: Issues from newspaper

1) The Star Online

Sunday, 11th April 2010



Too much noise in hospital ward

THE Kuala Lumpur Hospital medical and healthcare services have improved by leaps and bounds.

I had an operation recently and was hospitalised in its urology ward for six days. My heartfelt thanks go out to the doctors and nurses of the ward who have shown excellence in service and dedication.

However, the ward, situated next to Jalan Pahang, is bombarded with traffic noise coming from motorists and their loud exhaust pipes and honking, especially from buses. This disrupts patients' sleep and rest.

It is hoped that relevant authorities will check on these activities as driving with a loud modified exhaust pipe or honking in the vicinity of hospitals is an offence.

**ZAINOL IBRAHIM,
Kuala Lumpur.**

Listen please, we need a noise barrier

I'VE written many times about my concerns regarding the noise pollution on the LDP with hopes it will be highlighted.

Being a mother of three young children, my worries and concerns over the excessive traffic noise is genuine as it affects our health.

My intentions are not to make life difficult for any concerned party, neither is it for self interest.

Before proceeding to highlight this matter, my husband and I went from house to house along our street to seek support from our neighbourhood.

Once we understood they felt the same way about the noise pollution, we wasted no time in bringing this matter up with the relevant parties.

Unfortunately for us, residents

of USJ17/8 of Subang Jaya, no one seems to care the least bit about our problem. Since our houses face the LDP, we are exposed to the excessive traffic noise every single day of our lives. Based on guidelines set by the Department of Environment, the noise level is below the limit but on the other hand, it exceeds the World Health Organisation recommended guidelines for community environment.

My question is, why should our health, well-being and situation be any different or less than those who live along other major highways that already have noise barriers? Why are we the insignificant group? Why are we being subjected to an unhealthy environment? What happened to Litrak's corporate social responsibility?

I believe everyone wants what we want, to live in a serene and calm environment in the comfort of our homes.

We are not asking for total peace and tranquility, far from that. Just a certain level of serenity, to be able to open our windows and doors without the intrusion of traffic noise and pollution.

Why must noise barriers be a "request" from residents? Why do highway concessionaires wait for a formal complaint or a petition from affected residents before they can consider the best mitigating measures?

Aren't the highway concessionaires supposed to be more knowledgeable and well-versed in matters regarding the environmental impact of noise on people living adjacent to busy highways?

What effective roles do the government, the Malaysian Highway Authority and the Department of Environment play in ensuring the noise pollution issue is addressed appropriately, so as not to burden affected residents with the need to protest, complain, request and send petition letters?

This is an ongoing problem and a major cause of concern. We all know that statistics show the traffic volume is increasing every year, more so on the LDP, being the only connection linking Sri Damansara in the north and Putrajaya in the south.

You need to see and hear it to believe that my concerns are real. We need a noise barrier.

Nora
Subang Jaya

AKHBAR : SINAR HARIAN
TARIKH : 27-Jan-2008
KATEGORI ISU : KACAU GANGGU
TAJUK : 'Noise Barrier' penyelesaian masalah bunyi bising

SEKSYEN :
HARI : AHAD (SUN)
MUKA SURAT : S31

'Noise Barrier' penyelesaian masalah bunyi bising

Penduduk berharap agar pihak yang bertanggungjawab dapat membina 'Noise Barrier' di kawasan tersebut.

■ RANI ANN BALARAMAN

TAMAN BUKIT MEWAH FASA 8

Penduduk di sekitar Jalan Bukit Mewah 76 dan 77 mendakwa pembinaan Lebuhraya Sistem Lingkaran-Lebuhraya Kajang (Silk) sekitar tahun 2003 di hadapan rumah kini menjadi punca mereka diganggu bunyi bising dan tidak dapat hidup dalam keadaan aman.

Menurut mereka, jarak kedudukan rumah mereka yang hanya lebih kurang 40 kaki dari lebuhraya tersebut menyebabkan mereka terdedah dengan bunyi kenderaan yang dipandu dan kadang-kadang dikogulkan dengan bunyi kenderaan yang terlibat dalam kemalangan.

Seorang penduduk, KK Liew, 40, yang telah tiga tahun menghuni taman berkenaan berkata, sejak berpindah ke rumah tersebut, keluarga beliau tidak pernah menikmati keserasian.

"Keadaan menjadi bertambah buruk terutamanya pada waktu puncak ketika penduduk pergi dan

pulang dari kerja.

"Pada waktu tengah malam apa kurangnya kerana ada juga pihak yang tidak bertanggungjawab mengadakan lumba haram di kawasan ini. Bunyi motosikal yang dipandu laju sudah cukup untuk membuat kami sekeluarga tidak dapat tidur," katanya.

Keadaan menjadi bertambah buruk terutamanya pada waktu puncak ketika penduduk pergi dan pulang dari kerja."

■ KK Liew

Manakala seorang lagi penduduk, Leng Yuen For, 40, berkata, pada awal pembinaan lebuhraya tersebut, kawasan tersebut tidak begitu bising kerana bilangan kenderaan yang kurang dan jalan sekitarnya yang dipenuhi dengan semak.

"Tetapi setelah lebih 3 tahun lebuhraya tersebut siap, kenderaan bertambah banyak dan membawa masalah pencemaran kepada kami. Penduduk di sini jarang membuka pintu dan tingkap rumah kerana masalah bunyi dan



Low Hoon Hang (kiri sekali) dan beberapa penduduk Taman Bukit Mewah fasa 8 di sini menunjukkan surat yang dihantar kepada pihak lebuhraya berkenaan.

habuk berterbangan.

"Lagipun kawasan di hadapan rumah kami merupakan kawasan rendah di mana kenderaan dari arah Kajang akan melalui kawasan ini dengan laju sebab kawasan di atas taman ini boleh dikatakan agak tinggi," kata penghuni yang sudah mendiami taman tersebut sejak tahun 2000.

Sementara itu, Pengerusi Taman Bukit Mewah Fasa 8, Low Hoon Hang, ketika diminta

mengulas mengenai perkara ini berkata, pihaknya ada menulis surat kepada pihak Lebuhraya Silk dan menghantar salinan kepada pihak Majlis Perbandaran Kajang (MPKJ), ADUN dan Ahli Parlimen mengenai masalah ini dan mengharapkan pihak yang bertanggungjawab untuk membina 'Noise Barrier' di kawasan tersebut.

"Saya menghantar surat tersebut pada 26 Julai 2004, namun saya tidak fa-

ham mengapa 'Noise Barrier' tersebut boleh dibina di kawasan perumahan lain seperti di Taman Semarak tetapi di sini tidak," tambahnya lagi.

Menurutnya, pihaknya telah memaklumkan kembali perkara ini kepada Ahli Parlimen Serdang, Datuk Yap Puan Hoon mengenai perkara ini dan Yap berjaya untuk meneliti kembali masalah ini dan meminta penjelasan daripada pihak lebuhraya berkenaan.